UNIVERSITY OF MINNESOTA
College of Natural Resources
Department of Forest Resources

MINNESOTA TREE IMPROVEMENT COOPERATIVE

1999

ANNUAL REPORT

Prepared by:

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December 30, 1999

MEMBERS
Beltrami County
Blandin Paper Company
Bureau of Indian Affairs
Cass County
Crow Wing County
Georgia-Pacific Corp.
Iron Range Resources and Rehabilitation Board
Itasca County
Koochiching County
Lake County
Minnesota Department of Natural Resources
Mosinee Paper Corp.
Potlatch Corporation
Rajala Companies
St. Louis County
USDA Forest Service NCFES Forest Pathology and Genetics
University of Minnesota Department of Forest Resources

SUPPORTING MEMBERS
Becker County
Carlton County
Champion International Corp.
Clearwater County
Hedstrom Lumber Company
Hubbard County
Itasca Greenhouse
Minnesota Association of Soil and Water Conservation Districts
Pine County

TECHNICAL ADVISORS
USDA Forest Service State and Private Forestry
USDA Forest Service North Central Forest Experiment Station
University of Minnesota College of Natural Resources

EXECUTIVE SUMMARY

The Minnesota Tree Improvement Cooperative is now in its nineteenth year. During 1999, eighteen Full Members and nine Supporting Members provided funding and participated in activities conducted by the Cooperative. Genetic improvement programs are in place for black spruce, white spruce, jack pine, red pine, white pine, and most recently, Norway spruce. The establishment of new orchards and tests was the highest priority for 1999 during which four second-generation jack pine populations, three Norway spruce comparison trials, and three white pine field trials were planted.

Regular Cooperative expenses were about $5,000 less than budgeted for 1999. The Cooperative continues to administer the white pine research grant appropriated by the Minnesota State Legislature in 1997, which was recently renewed for the next biennium. Cooperative staff made about 51 on-site visits with cooperators, resulting in about 378 hours of work on specific projects for individual cooperators. The year began with the resignation of Dr. Robert Stine from his post as Director of the Cooperative. The new Director is Dr. Andrew David, who was recently hired by the University of Minnesota as an Assistant Professor of Tree Improvement. He will provide the Cooperative with long-term direction, breeding strategies and serve as a direct link to the University of Minnesota. Carrie Pike has taken over daily activities of the Cooperative and Jim Warren was hired on a temporary appointment primarily to assist with the white pine project. The Advisory Committee held two regular meetings, and five members participated in a joint meeting with the Maritime Seed Orchard Manager's Workshop in Moncton, New Brunswick. Pike presented a summary of the Cooperative's accomplishments at that meeting.

In all there are 39 seed orchards covering about 134 acres and containing approximately 25,000 trees. The cone crop was low this year for all tree species except jack pine. Ten bushels of jack pine cones (800,000 seeds) were collected by one cooperator. Cone crops on white and black spruce were low state-wide, prohibiting efforts to complete the controlled crosses of white spruce for the second generation. Preparations are being made for completion of crosses in 2000. Several red pine orchards are approaching maturity and will likely produce a sizeable crop in the next year or two. Heights and diameters were taken from the St. Louis County red pine seed orchard which will be rogued either winter 2000 or 2001.

Most first generation seed orchards have been rogued, and four second-generation jack pine populations were planted this spring. Substantial progress is being made in white pine blister rust research, with distinct genetic differences displayed among tested families.

The outlook for 2000 includes a variety of field tasks and planning. Field tasks will consist of additional controlled crosses in white spruce, planting ramets of white pine at Rajala/Itasca orchard, transplanting ramets into Koochiching County's black spruce orchard, and monitoring/maintaining new orchards planted in 1999. Research on white pine blister rust research will continue, and research on flower stimulation using injected $GA_{4/7}$ will continue. In the midst of all these new efforts, accelerated management of existing seed orchards is critical for enhanced seed production.

TABLE OF CONTENTS

For more than nineteen years, members of the Minnesota Tree Improvement Cooperative have conducted activities to increase the genetic quality of seedlings planted in Minnesota and Wisconsin. Along with some minor setbacks, steady progress has been made in five species for which genetic improvement programs have been established (black spruce, white spruce, jack pine, red pine, and white pine). One additional species (Norway spruce) was added in 1999. The Cooperative is poised to make significant advances in the next three to five years particularly in white spruce, red pine, and white pine. During 1999, eighteen Full Members and nine Supporting Members (see Appendix II) provided funding and participated in activities conducted by the Cooperative.

High priority activities during the year included planting four replications of second-generation jack pine, three replications of Norway spruce comparison trial, and three replications of white pine field trial. Grafting for clonal orchard development in white spruce and white pine is ongoing, and white pine blister rust research and related activities are also in progress.

This report describes the Cooperative's programs and summarizes activities and accomplishments from January 1 to December 31, 1999. It is organized into five sections: administration, finances, seed orchards, species reports, and outlook. Appendix I contains a summary of the Seed Orchard Manager's Workshop held in Moncton New Brunswick in October 1999.

ADMINISTRATION

Dr. Robert Stine officially resigned as Director of the Cooperative January 1, 1999 to accept an administrative position within the University at the Cloquet Forestry Center. He was replaced by Dr. Andrew David, Assistant Professor of Tree Improvement at the University of Minnesota. A Personnel Committee was formed at the January 1999 Advisory Committee meeting to explore personnel options for the Cooperative. The Personnel Committee's suggestion to give C. Pike a raise in salary, control of the day-to-day operations of the Cooperative and require her to take several courses related to tree improvement under the University's Reagent's Scholarship, was approved at the March 1999 Advisory Committee meeting.

Jim Warren was also hired on a dual-appointment working on the white pine project and for the Cooperative. For the white pine project he managed the expansion of the white pine breeding arboretum, assisted with planting field trials of white pine for P. Zambino's research, and also helped to erect a deer-proof enclosure around the field trial in Grand Marais. His Cooperative duties were varied and included extracting seed from white spruce cones, assisting with site preparation and planting in the spring, visiting selected orchards, and assisting Pike with the software transition from dBASE to Microsoft Access.

The Advisory Committee consists of representatives from each member of the Cooperative. It met three times during 1999, twice for regular meetings and once in a joint workshop with the Maritime Seed Orchard Manager's Workshop in Moncton, New Brunswick. The workshop focused on seed orchard management in the Maritimes, and was attended by approximately 50 Canadians and five representatives from Minnesota including Pike, R. Klevorn (MN DNR), D. Jordan (IRRRB), M. Pannkuk (St. Louis County) and Q. Legler (Itasca Greenhouses, Inc.). At this meeting C. Pike presented a

summary of the Cooperatives accomplishments and future plans. A meeting summary, similar to one that was included in the October monthly report, may be found in Appendix I.

About 55 on-site visits were made by Pike, Warren, David, and Stine this year to members of the Cooperative. A range of planning and field activities occurred during these visits, resulting in about 652 hours dedicated specifically to contact with individual Cooperators. The number of site visits was higher than usual this year due to the busy planting season in the spring. Other field visits covered a variety of activities, including seed orchard management, progeny test visits, cone collections, and planning sessions.

SEED ORCHARDS

Seed orchards are the primary means by which genetically improved material is produced for use in commercial-scale planting programs. Beginning in 1967, members of the Cooperative have established 35 seed orchards, many of which are still used for seed collection. Most of those orchards (27) were established since 1981, and two were added during 1998. Three of the orchards are improved first-generation orchards, four are full-sib second-generation populations, and all the rest are first generation seedling or clonal orchards. Nearly all the first generation orchards are rogued. A summary of the types and sizes of orchards managed by members of the Cooperative is shown in Table 3. Table 4 lists all orchards by species and owner.

Table 1. Acres of seed orchard by species and orchard type (1999).

Orchard type	Black Spruce	White Spruce	Jack Pine	Red Pine	White Pine	Total	%
1st generation, seedling				22		22	16%
1st generation, clonal		8.4			9.8	18.2	14%
1st generation, rogued	8.2	16.1	31.7	20.2		76.2	57%
Improved 1st generation	5.8					5.8	4%
2nd generation, full-sib seedling			11.6			11.6	9%
Total	14	24.5	43.3	42.2	9.8	133.8	100%
%	10%	18%	32%	32%	7%	100%	

Table 2. Seed orchards of Minnesota Tree Improvement Cooperative, 1999.

Species	Organization	Orchard	Established	Size (ac)	Live Trees
Black spruce	Blandin Paper Company.	Blackberry	05/22/78	2.5	596
	Koochiching Co.	Big Falls	05/19/89	2.3	63
	Koochiching Co.	Larsaybow	05/27/98	1.1	56
	Minnesota DNR	Eaglehead	05/17/98	2.7	582
	Minnesota DNR	Split Rock	05/27/92	2.4	261
	Potlatch Corp.	Cloquet	05/05/78	3.0	580
Jack pine	Bureau of Indian Affairs	Sand Lake	05/23/88	1.6	268
	Cass/Beltrami/Hubbard Co.'s	Deep Portage	10/08/82	3.4	492
	Crow Wing Co.	Crow Wing	06/04/85	2.1	323
	IRRRB	IRRRB	09/16/82	1.7	245
	Minnesota DNR	Bemidji	05/30/84	2.5	406
	Minnesota DNR	Nickerson	05/15/84	2.4	407
	Minnesota DNR	Staples	05/18/84	4.0	501
	Wausau-Mosinee Paper Corp.	Barnes	05/27/88	4.1	548
	Potlatch Corp.	Cloquet	06/28/83	5.5	171
	Potlatch Corp.	Kallstrom	05/01/74	2.8	282
	St. Louis Co.	Ellsburg Rd.	05/10/88	1.6	280
	Cass/Beltrami/Hubbard Co.'s	Leech Lake	05/18/99	2.6	1800
	St. Louis Co./ IRRRB	North Side	05/12/99	3.8	2574
	Potlatch Corp.	Haltberg Rd.	05/11/99	2.6	1800
	Crow Wing Co./MN DNR	Cty Line Rd.	05/07/99	2.6	1800
Red pine	Cass/Beltrami/Hubbard Co.'s	Blind Lake	09/10/91	5.3	2249
	Georgia-Pacific Corp.	Petenwell	04/24/90	5.5	1576
	Georgia-Pacific Corp.	Ashwabay	09/17/85	5.5	405
	Minnesota DNR	Cotton	07/29/81	4.5	466
	Minnesota DNR	Eaglehead	06/25/81	3.6	388
	Wausau-Mosinee Paper Corp.	Wascott	05/23/90	5.7	1174
	Potlatch Corp.	Cloquet	07/10/81	6.6	761
	St. Louis Co.	Ellsburg Rd.	05/09/88	5.5	2235
White Pine	Minnesota DNR	St. Francis	05/15/85	3.0	238
	Rajala/Itasca Co.	Bass Lake	05/19/98	5.7	231
	St. Louis Co.	Ellsburg Rd.	05/02/90	1.1	233
White spruce	Blandin Paper Company	Lattimer	05/15/67	4.1	244
	Blandin Paper Company	Arbo	05/01/76	1.5	197
	Itasca Co.	Fig.-8-Lake	09/02/87	1.1	150
	Lake Co.	Two Harbors	09/02/87	1.0	132
	Potlatch Corp.	Cloquet	05/01/77	3.3	140
	St. Louis Co.	Ellsburg Rd.	05/11/88	1.5	140
	Minnesota DNR	Cotton	05/01/77	12.0	206

Cone Collections

There was a low cone crop in several species in 1999. About 10 bushels of jack pine cones were collected from the Crow Wing County seed orchard. They should average about 10 ounces of seed per bushel, or about 800,000 seeds. No white spruce, red pine, or white pine cones were collected due to poor cone crops in these species.

The red pine orchards at Potlatch, DNR's Cotton, and Georgia-Pacific's Ashwabay are near maturity. There were too few cones to justify collection at Potlatch, and less than a bushel of cones were collected at Cotton. However all three of these orchards should be producing sizeable cone crops within the next few years.

SPECIES REPORTS

The Cooperative continues to work at various levels of intensity on six conifer species: black spruce, white spruce, Norway spruce, jack pine, red pine, and white pine. The intensity level varies among species depending on Cooperator interest, type of breeding plan, and available resources. In all cases, the goal is to maximize genetic gain using available resources. A review of the improvement program for each species follows.

Black Spruce

Status

Three black spruce seedling seed orchards planted in 1978 were rogued in 1987 to about 600 trees each. Combined they cover about 8.2 acres. Koochiching County plans to re-establish its improved first generation black spruce orchard because of soil moisture problems on the original site. Seventy-three new ramets were outplanted in the spring and fall of 1998. Ramets from the old orchard will hopefully be moved to the new site in the spring of 2000. The Minnesota DNR established a similar improved first generation black spruce orchard at the Split Rock seed orchard complex in 1992. It now contains 280 ramets representing 20 clones and covers 2.4 acres.

Short and Long-term Planning

Establishment of the Koochiching County improved first generation seed orchard needs to be completed using existing grafted material. It and the DNR orchard will produce offspring with about 8-9 percent improvement in height growth over wild seed. Additional genetic gain, if desired, will come through controlled crossing and full-sib progeny tests.

Because of the vast expanse of lowlands in Minnesota, black spruce is an important species in northern forests. However, relative to other species it is a low priority for further genetic improvement activities. Sufficient material exists for breeding and development of advanced generations with increased genetic gain, but the Cooperative will not continue with advanced generation efforts in the near future.

The three seedling seed orchards should be managed to provide improved seed. Substantial amounts of black spruce seed for aerial seeding programs are used annually, and there has been some difficulty in acquiring enough seed in recent years. At the same time, reasonably good cone crops are not always collected from most of the black spruce orchards. If collected when available, and stored properly, seed from these existing orchards could help supply the demand for seed, with the added benefit of providing improved growth rates. For this to happen, organizations will need to work together to make sure that available cone crops are harvested.

Norway Spruce

Blandin Paper Company is interested in growing Norway spruce on some sites as an alternative to white spruce. The company provided additional funding to the Cooperative in 1998 and 1999 to compare different sources of seed. Seedlots from genetic improvement programs in Finland, Sweden, and Quebec were acquired and planted in the spring of 1999. The seedlots were planted on three sites near Grand Rapids. The goal is to identify a good source of Norway spruce seed for north central Minnesota that is readily available to Blandin for use on their lands.

White Spruce

Status

Genetic improvement of white spruce in Minnesota has involved two separate sets of material. One set comprises clonal material originating in southeastern Ontario, Canada, represented in several clonal orchards. A second set of white spruce material consists of native Minnesota sources selected in the wild based on better than average growth. This set of material is represented in Blandin's Lattimer (formerly Zigmund) orchard. Since 1988, white spruce seed orchards in the Cooperative have produced more than 1,300 pounds of seed. The orchards are producing enough seed to meet basic needs of most organizations, however members have expressed an interest in improving the quality of the seed produced in orchards that have not been fully rogued.

An open-pollinated white spruce progeny test was established in 1986 to test as many families as possible. The test was measured and analyzed after ten growing seasons. Last summer, the Lake County progeny test (Finland) was thinned to half its size. Blandin/Itasca County's progeny test at Nine-Mile Lake was thinned in summer 1999. Nickerson (MN DNR) is set to be thinned early in the summer of 2000 so that next year 15-year measurements can be taken at all three sites. St. Louis County (Rabbit Lake) and MN DNR (Ross Lake) will not be thinned due to high mortality at both sites. The older clonal seed orchards have been rogued using information from the progeny test. Gains from roguing generally fall in the range of five to seven percent above the orchard mean. Blandin's Lattimer and Arbo orchards were rogued this year also using information from progeny tests.

When the progeny test was started, grafts of as many parents as possible were also made and the ramets were outplanted into a breeding orchard at General Andrews Nursery. Using results from the progeny test, controlled crosses were performed in spring 1998 using a single pair, assortitive breeding

scheme (top ranked clone crossed with second ranked clone, third with fourth, etc.). Flowers were abundant on most trees during 1998, allowing the completion of approximately 90 crosses. Seed extraction and separation were completed in the winter of 1999. Preliminary tests indicate that germination rates are very low, and further tests will be conducted this winter to determine if certain families exhibit exceptionally poor rates. Subject to the results of this germination test it may be prudent to repeat many crosses. Other crosses not made in 1998 will be made as well.

The Cooperative currently has two white spruce seed source comparison trials. The first, planted in 1993, was measured, analyzed and the findings reported in the 1998 Annual Report. A second white spruce comparison trial established in 1995 includes a patented "Elite" white spruce from ForGene, Inc., a clonal seed orchard source, and a woods-run source. It will be measured early this spring to obtain heights after five growing seasons.

Short and Long-term Planning

Based on the progeny tests several improved first generation orchards are planned, using the best 20 to 25 clones available. Grafting success during the first few years of the project was lower than anticipated, but success this past year was excellent. Blandin and the Minnesota DNR are planning to develop such orchards. Several other 1st generation seed orchards have not been rogued (Figure-8-Lake, Two Harbors, and Ellsburg Rd). Plans are being made to remove families that performed poorly on progeny tests, and to replace them with better clones, converting the orchards to improved-first generation orchards.

Second-generation white spruce seed from controlled crosses made in spring 2000 should be available for sowing in a greenhouse by winter 2001. Three organizations, MN DNR, Blandin Paper Co., and Itasca Co. have volunteered to have sites planted on their land. Site location and preparation should begin in 2000. These will be second generation populations, and do not require pollen isolation from other white spruce. However, site preparation should be sufficient to allow high survival and a good quality test.

Jack Pine

Status

Members of the Cooperative manage twelve 1st-generation jack pine seed orchards that are a variety of ages and include various sets of genetic material. Cone production is common in the orchards, and collections are made in half a dozen or more orchards every year. Cone collections are relatively small, but generally supply the demand for seed by members of the Cooperative. Total yield from cones collected in 1999 is estimated to be 800,000 seeds.

Following several years of controlled crosses, site preparation and seedling production, second-generation jack pine populations were outplanted in the spring of 1999. A total of four replications were planted. Three sites (Cass/Beltrami/Hubbard Co.'s, Potlatch & Crow Wing Co./MN DNR) contain 18 blocks of 100 families each. The site at St. Louis Co. in cooperation with IRRRB

contained 18 blocks of 143 families each. This disparity was due to an insufficient number of replications for the 43 families contained at St. Louis but not at the other three sites. The spring and summer of 1999 were very wet, which may have contributed to the success at two sandy sites (St. Louis Co./IRRRB, DNR/Crow Wing Co.), but also likely hindered the other two planted on less-sandy soils (Cass Co. and Potlatch). These sites will be revisited again this spring and again in the fall to observe progress. Fences were in place around three of the sites and wire cages are used at the fourth (Cass Co.).

Short and Long-term Planning

Existing first generation jack pine orchards need to be managed to continue seed production. Seed from the second-generation orchards will not be available in quantity for at least another 10 years. In the mean time, these orchards must be monitored for disease and mortality and herbaceous competition should be controlled.

Two of the three jack pine orchards in Wisconsin (BIA and Wausau-Mosinee) have been rogued. The third was established by Nekoosa Papers (now Georgia-Pacific) and is now owned by Great Lakes Nursery. It has not been measured or rogued. This orchard should be measured as soon as possible (assuming access is granted). Controlled crosses should be made in these orchards for establishment of second-generation full-sib progeny tests, using a design similar to the one employed in Minnesota. Crossing work could begin as early as 2001.

Red Pine

Status

Eight red pine orchards, ranging in age from 5 to 17 years, are all growing well and are being managed to promote growth and cone production. Heights and diameters were taken from the St. Louis County orchard in preparation for roguing. Statistics on that data will be used to compare heights with overall volume among families. The older orchards are producing limited numbers of cones, which should slowly increase with time. Observations made at the MN DNR's Cotton orchard in the summer looked promising, but less than one bushel of cones were collected. There is widespread interest in dramatically increasing cone production in the orchards, and also expanding orchard acreage.

Short and Long-term Planning

Red pine is the most widely planted conifer in Minnesota and Wisconsin. The seed orchards within the Cooperative were planted for seed production with the objective of obtaining maximum genetic gain. The late age at which red pine begins flowering prolifically (15-20 years) slows the advancement from one generation to the next, and flowers at the top of the crown are difficult to reach for controlled crosses. In the short term, flower production might be increased using management tools such as herbaceous control and fertilization, at the very least. Use of injected gibberelic acid ($GA_{4/7}$), a flower inducing hormone, holds promise for increasing flower production, and perhaps for reducing the initial age of flowering. Future trials to establish a methodology will hopefully continue in the future. In addition,

fertilization may hold promise for increasing cone crops in the future as well. While $GA_{4/7}$ may not be feasible for all organizations due to labor and cost requirements, efforts aimed at using fertilization more effectively may produce adequate results in some orchards.

Attempts to graft red pine during the last few years have had limited success. However, learning continues, and there is still optimism that a successful technique will be found. Once grafting is possible, improved first generation seed orchards could be established in a relatively short time frame. Such orchards would provide genetic gain over the seedling seed orchards and a relatively rapid expansion of orchard acreage and seed production. Following establishment of improved first generation orchards, controlled crosses will take place to develop a full-sib second generation population.

White Pine

Status

For the past several years the Cooperative has been involved in white pine improvement. The Rajala/Itasca Co. seed orchard was established from individuals possessing superior growth or form. Scion material from these grafts was collected last winter to increase the number of ramets in the orchard but scions were problematically small and a majority of the grafts did not take. Efforts will be made this winter to collect scion material from the original parent trees, graft them to potted rootstock and plant in the orchard once they reach acceptable size.

In 1997 the Minnesota state legislature set aside $300,000 over two years to reduce the impact of white pine blister rust on the state's precious white pine resource. The Cooperative was chosen to administer that grant and a subsequent one that will run through June 2001. These monies have been used to approach the white pine blister rust problem from two different directions. One is to understand the mechanisms surrounding the interaction of white pine blister rust and its host, eastern white pine, and to identify different levels of resistance within test populations. The second is to establish a breeding population of white pine individuals, some with elevated levels of rust resistance and others with above-average growth and form and understand how to induce early flowering. This two-pronged approach will allow the Cooperative to screen potential parents for resistance mechanisms and then cross individuals with compatible mechanisms to increase resistance levels in the improved seedlings.

A full description of research programs associated with the white pine blister rust reduction grant can be found at www.cnr.umn.edu/FR/research/centcoop/mtic/wpine.html. Below is a brief summary of the status of these research programs.

Early screening for blister rust resistance

Accelerated Artificial Screening for Resistance

Until recently, resistance to blister rust has only been studied in the field. Such studies require observations throughout the entire life of a tree before resistance can even be implicated as the cause for a tree's lack of infection. However, many trees manage to evade disease simply by chance. These trees

may be characterized as resistant despite never being infected. Thus, true resistance has yet to be confirmed. An early screening method will allow breeders to determine the level of resistance of a particular parent by screening young progeny of that parent in the laboratory. The experiments being conducted in the white pine project are designed to determine a suitable age for screening seedlings and to make preliminary judgements on levels of resistance. Four different experiments used white pine seedlings ranging in age from 5 to 16 months in which the seedlings were inoculated with spores of the white pine blister rust fungus *Cronartium ribicola*. The seedlings represent open-pollinated and/or control-pollinated seed from white pine both with putative resistance and others that were selected for superior silvicultural traits, such as rapid growth. Once seedlings were infected, the number and size of needle spots were determined at 5 weeks; extent of stem infection determined at 12 weeks; and mortality was determined every 2 weeks for up to 104 weeks following infection.

Three of the four experiments are finished and together they point to some interesting conclusions. Because none of the seedlings were immune (complete absence of infection) none of the tested seedlings possessed a major gene trait for resistance. This coupled with the fact that distinct mortality classes could not be identified when plotting death over time suggests that resistance to white pine blister rust in white pine is polygenic, i.e. composed of a number of genes each contributing a small portion to the level of resistance. Although this type of resistance is more difficult to select in individuals, it is considered to be a more stable form of resistance when compared to a major gene trait because the loss of any one gene has a relatively small impact on the overall level of resistance.

All of the susceptible families had more rapid onset of disease symptoms and reach the 50% level of mortality faster than any of the resistant families. Continuing this trend, seedlings from controlled crosses between resistant individuals had greater levels of resistance than open pollinated crosses from the same parents. Thus random mating among a small group of resistant clones as in a seed orchard may be one way of obtaining seedlings with elevated levels of resistance.

Correlation between seedling assays and field resistance

In the experiments above young seedlings are inoculated in ideal conditions for infection; 100% relative humidity, 18^0 C and extremely high levels of basidiospores. These conditions are rarely found in the field and a correlation is needed to determine how to translate greenhouse inoculation studies into a prediction of field performance. To determine this four field experiments were established this past spring using seedlots that had been used in the early screening studies. These field studies are designed to run a minimum of 5 years and will be monitored yearly for mortality, infection levels and rate of canker growth.

Mechanisms of resistance

As part of the overall project seedlings are inoculated, grown in the greenhouse and transported to the Department of Plant Pathology in St. Paul where histological work is being done in an effort to elucidate the actual resistance mechanisms for particular parents.

Genetic diversity of the rust fungus

This work has been initiated to determine the level of differentiation between eastern and western populations of white pine blister rust. Cooperative research on DNA markers done in conjunction with Dr. Richard Hamelin, University of Lavalle, St. Fay, Quebec, has demonstrated that there is a high degree

of genetic differentiation between the eastern and western populations of white pine blister rust, confirming separate introductions on the east and west coasts and indicating that there has been little interaction between the two different populations of rust. In addition, the eastern population has higher levels of diversity than the western population.

Histological characterization of rust resistance mechanisms

Seedlings from susceptible and resistant families inoculated with the blister rust fungus were sectioned and analyzed for a variety of host responses. Seedlings from susceptible families produce diffuse needle lesions that increase in size to several cm of the needle in a few months. Micrographs of needle sections indicate that the hyphae of the fungus grow virtually unchecked throughout the mesophyll cells of the needle tissue.

Seedlings from resistant families produce fewer and smaller lesions than their susceptible counterparts. Micrographs of needles from these individuals indicate a reaction zone in advance of the fungus that restricts growth and localizes the infection. Two factors that may be contributing to the establishment of the reaction zone are the production of small amounts of defense compounds and host cell death. Variations in the amount of defense compounds produced and the rate or extent of host cell death account for differences in the amount of resistance observed. Those individuals that are best at compartmentalizing the fungus show the highest levels of resistance.

Another area of investigation being pursued is the effect of chemical elicitors and specific strains of rhizobacteria on the general host response to fungal infection. The chemical elicitors would promote the production of plant defense chemicals important to the formation of reaction zones and the specific rhizobacteria strains would colonize seedling roots and cause a systemic response that limits subsequent fungal infection. The efficacy of these treatments to reduce the impact of white pine blister rust on young seedlings, and to improve assays for resistance is being investigated.

Stimulation of early flowering in eastern white pine

Three ramets each of 53 grafted white pine clones at the Cloquet Forestry Center were used to test the effect of a foliar application of $GA_{4/7}$, ProCone, or control on the formation of male and female flowers. Weekly foliar applications during the period of rapid shoot induction from mid-May through July appear to be able to induce flowers on eastern white pine but flower induction was not uniform among genotypes, nor by sex of flower. Twenty-five out of 53 clones produced male inflorescences, and 19 of 53 produced female inflorescences. The production of male inflorescences responded to $GA_{4/7}$ or ProCone, while female inflorescences were produced primarily by ProCone. A small group of eight clones produced both male and female inflorescences.

The study continues in order to increase both male and female flowering across all genotypes tested. Stem injection trials of $GA_{4/7}$, ProCone, or ethanol (controls) were initiated. The critical time of year for stem injections, concentration of $GA_{4/7}$ or ProCone, fertilization of trees, and effects on pollen viability will be determined as the study continues.

Field testing and establishment of seed orchards

Physical expansion of the white pine breeding arboretum at the Cloquet Forestry Center was completed, to roughly double the original size. In addition, the fencing was extended to encompass the entire arboretum and a trickle irrigation system was added. The Cooperative assisted in the establishment of three field trials to define correlation between early screening for white pine blister rust resistance and field performance as mentioned above. Late season mortality surveys in these field tests were performed. On one site near Tofte, MN a fence was erected around the entire perimeter to protect seedlings from herbivory. One of Cliff Ahlgren's second-generation test sites was cleaned out and plots were reestablished. In cooperation with George Host, NRRI, Duluth, a GIS map of the state was created using landform, proximity to water and incidence of *Ribes* spp. to indicate high, medium and low risk planting sites for white pine.

OUTLOOK

The Minnesota Tree Improvement Cooperative has entered the new millennium with a full set of first generation seed orchards, one second generation population in the ground, and another one coming soon. With several seed orchards approaching maturity seed orchard management, including manipulation of nutrient levels, $GA_{4/7}$ applications and herbaceous competition control needs to continue on a regular basis until a successful flower induction method is developed. Several lessons of Moncton include the importance of seed orchard management in a breeding program, especially the need to capitalize on the benefits of fertilization and/or gibberellic acid treatments.

The red pine program is also looking to new horizons as we try to determine methods that will maximize gains for this vital tree species. If breeding programs in white pine, red pine, and Wisconsin's jack pine are to be continued, additional personnel will be needed to perform controlled crosses to produce second generation populations.

The original goals of the Cooperative, to improve genetic gain and maintain a broad genetic base for a variety of important tree species, remain the same. To ensure that our programs can be continued at the same rate, membership needs to be expanded to consider hiring additional personnel. Within the Cooperative's breeding program, other factors including volume, and wood quality should be considered to enhance genetic gains for all members. A protocol for white pine breeding program will be established upon the completion of the blister rust research. The Cooperative will be one of the first organizations to breed trees with the best hope for resistance.

Annual Work Plan

White spruce:

- Complete second-generation controlled crosses
- Plan and prepare sites for improved first-generation orchards

Red pine:

- Increase level of seed orchard management

- Field grafting

White pine:

- Continue managing grant money
- Continue grafting for Rajala/Itasca seed orchard
- Perform mortality survey for field trials planted in spring 1999

Black spruce:

- Complete transfer of Koochiching County seed orchard

Jack pine:

- Mortality survey of second-generation populations

Other:

- Solicit new membership
- Organize fall workshop
- Arrange visit by Ron Smith
- Continue transition from dBASE to MS Access
- Measure heights and diameters from Finland, Nine-Mile Lake, and Nickerson white spruce progeny tests

APPENDIX I

Summary of Maritime's Seed Orchard Manager's Workshop
October 13–15 1999 Crystal Palace Hotel
Dieppe, New Brunswick, Canada
Sponsors: Ron Smith and Laurie Yeates (Canadian Forest Service)

A progress report was provided by each organization (approx. 10 in all) will be compiled and published in the meeting Proceedings, so I won't give details here. Overall, managers reported problems with yellow-headed spruce sawfly, spider mites (it was a very dry year for the Maritimes) and spruce gall aphids. This was generally a poor year for spruce cones that was not offset by repeated, annual applications of $GA_{4/7}$.

With the exception of J.D. Irving, most organizations utilize some form of top pruning to keep trees short. In white spruce, this can often result in an abundance of cone production on the multiple leaders. In jack pine top pruning is often utilized. Cones are generally abundant on this species and top-pruning has not put an obvious dent in cone production. This practice has been used in Minnesota orchards on jack pine but generally not on white spruce. Since observing abundant cones on all available leaders of pollarded trees, this is worth considering in our spruce orchards as well.

The New Brunswick Tree Improvement Council and Nova Scotia Tree Improvement Co-op have each planted a "mini-orchard," which are used to facilitate breeding efforts. The mini-orchard consists of single-clone rows (approx 25 clones per row). Trees are kept short (< 8' tall), and because all the clones are kept together, breeding is easier (no need to run around an orchard looking for clones that are scattered across the site), and the clone is easily replaced by removing the entire row. This type of orchard may be classified as high maintenance, however, as it involves annual pruning, along with turf management, fertilization, and usually some type of gibberelic acid treatment. This type of orchard may be worthwhile for sites that are guaranteed to receive frequent and careful maintenance.

Nearly all the Canadian organizations have utilized $GA_{4/7}$ applications in their spruce (black and white spruce) orchards. It remains untested in the pines, but Ron Smith reported operator success in white pine. During our visit to J.D. Irving, representative described methods for its application, (time of year, how much, concentration, etc).

Most organizations in the Maritimes have established second generation white and black spruce orchards. Some organizations utilize jack pine, but none utilize red pine. White pine has not achieved the popularity in recent years like it has in Minnesota, but some are foreseeing a change in its status in the future.

Several organizations are using rooted-cuttings in black spruce, instead of traditional grafts. It is easy to mass-produce seedlings, and it is substantially cheaper. However, it appears to be most efficient on a large scale. They have had good success with their rooted cuttings, something we may want to explore in the future. Pike obtained pamphlets from Michel Rioux, (Forêt Québec Pépinière de Saint-Modeste) related to the use of cuttings and associated methodologies and recommendations.

Ron Hallet (Atlantic Forest Nursery Co-op) summarized the effect of fertilization and different nutrients on tree nutrition. Several good points were made: there is a net acidity in the soil associated with fertilizers, which may be offset using lime. However, soils with high pH's are problematic in spruces and may influence the incidence of butt rot. Organic matter in the soil improves soil structure, supplies nitrogen to trees, improves water filtration, and increases soil exchange capacity. It's a good idea to survey foliage for the proportion of nitrogen to other nutrients to determine if fertilizing should be done, and if so, what type. Phosphorus in soils is difficult to manage, as it is fixed by iron or aluminum in acidic soils, and fixed by calcium in basic soils. Symptoms of deficiency include "purpleish" seedlings.

Potassium is often deficient in coarse-textured soils, and is frequently correlated with a Mg deficiency. Overall lesson: managers should access the nutrient content of foliage and soil on a more regular basis to identify nutrient deficiencies before growth is substantially impacted.

Ron Smith (Canadian Forest Service) gave a presentation on Ammonium nitrate and $GA_{4/7}$ on black spruce. The combination of fertilizing and gibberelic acid is often favorable for cone production, but there is a threshold that can be surpassed. Seed yields can be reduced if "too many" cones are produced.

Kathy Tosh (New Brunswick Tree Improvement Council) presented an overview of the New Brunswick Tree Improvement Council. This organization, which has been active for 20+ years is involved with four species, jack pine, tamarack, black and white spruce. Current membership consists of seven "licencees", the University of New Brunswick, the provincial government, and the University of Moncton.

Orchard visits included J.D. Irving, Nova Scotia Tree Improvement Cooperative, and Kimberly Clark.

Papers distributed at the meeting:

1. Simpson, D. and K Tosh. 1997. The New Brunswick Tree Improvement Council is 20 years old. For. Chron. 73 (5): 572-577.
2. R. F. Smith. 1993. Operational cone induction in black spruce seedling seed orchards: what do we know after five years?
3. R. F. Smith. 1995. Improving the genetic quality of orchard seed. Proc. Second Annual Ontario Seed Orchard Manager's Workshop, Sept. 12-14.
4. R. F. Smith. Using fertilizers to induce flowering in black spruce
5. R. F. Smith. 1995. Methods and procedures for use of $GA_{4/7}$ in seed orchards
6. R. F. Smith. 1998. Application of Gibberellin A4/7 to stimulate flowering in conifers and to accelerate breeding. Proc. 25th Annual Plant Growth Regulation Soc. America. Chicago, Illinois, July 7-10.
7. R. F. Smith. 1999. Some facts and foibles about forestry biotechnology? Proc. Eleventh Maritime Seed Orchard Manager's Workshop. Moncton, New Brunswick, October 13-15 1999.

APPENDIX II

MINNESOTA TREE IMPROVEMENT COOPERATIVE

1999 ADVISORY COMMITTEE

MEMBERS

Beltrami County	Bob Milne
Blandin Paper Company	Jim Marshall
Bureau of Indian Affairs	Jay West
Cass County	Mike Wadman
Crow Wing County	Tom Cowell
Georgia-Pacific Corp.	Doug Maurer
Hubbard County	Allen Lysdahl
Iron Range Resources and Rehabilitation Board	Dan Jordan
Itasca County	Brad Jones
Itasca Greenhouse Inc.	Bill Sayward
Koochiching County	Dave Larson
Lake County	Bill Nixon
Minnesota DNR - Forestry	Rick Klevorn
Potlatch Corporation	Mike Fasteland, Tom Murn
Rajala Companies	Beth Jacqmain
St. Louis County	George Kirk, Mark Pannkuk
Univ. of Minnesota Dept. of Forest Resources	Alan Ek
USDA Forest Service NCFES Forest Pathology and Genetics	Charles Michler
Wausau-Mosinee Paper Corp.	Pat Scheller

SUPPORTING MEMBERS

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Clearwater County	Greg Smith
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Minnesota Assoc. of Soil & Water Conservation Districts	Lee Anne Buck
Pine County	Bob Pulford